

# Cognitive Task Analysis for Defining AC OPF

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# Outline

1. Cognitive Task Analysis for Power System Operators
2. Applications for AC OPF
3. Simulation Test Beds and Open Source Applications
4. Summary

# Cognitive Task Analysis (CTA) for Power System Operators

# Communication Barriers

Utility  
System  
Operator



Substations  
Breakers  
Switching Orders  
EMS, DMS User

Utility  
Operations  
Engineer



Buses  
Branches  
Power Flow  
Transient Stability  
PSSE, PSLF  
System Protection

Power  
System  
Application  
Developer



FORTRAN  
MATLAB  
VB  
Decoupled Power Flow  
Jacobian Matrix  
Eigen Vectors  
Transient Saliency  
PSSE, PSLF  
EMS, DMS Apps

Software  
Developer



Java  
C++  
OO Programming  
OO data base  
Threads  
Network  
Cyber Security  
Linux  
CIM XML  
EMS, DMS SW.



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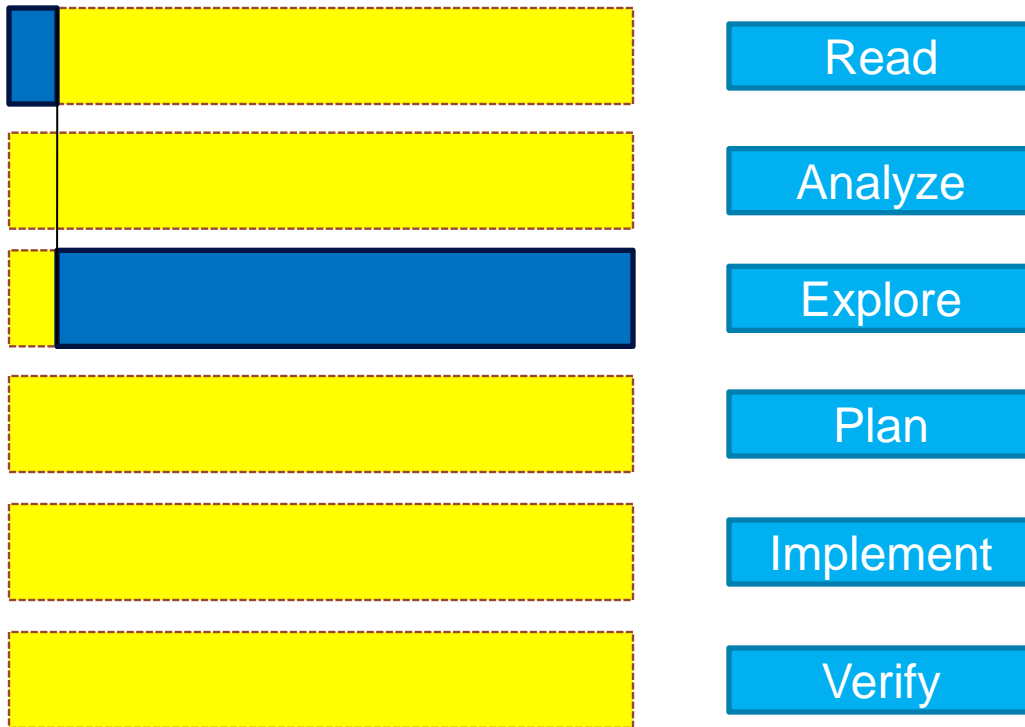
# Levels of Expertise

- Stage 1 Novice – Explicit rules susceptible to context and nuance
- Stage 2 Advanced Beginner – Nuance and context begin to be recognized and incorporated
- Stage 3 Competence - Transition from calculated effort to intuitive solutions
- Stage 4 Proficiency – Scenarios are now being recognized as whole parts, some analysis and conscious choice remains
- Stage 5 Expertise – Complete contexts are recognized and performance is fluid and unconscious.

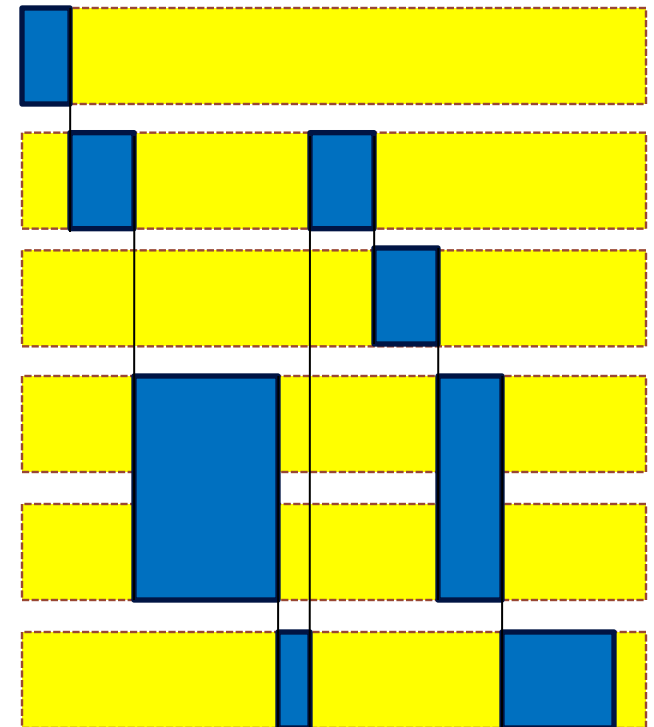
Dreyfus, H. L., & Dreyfus, S. E. (1986). Mind over machine: The power of human intuition and expertise in the era of the computer. New York: Free Press.

# Novices vs Experts

Novice Pattern



Expert Pattern



# Simulator Based Job Aids

Goal: Match People and Technology to 'Functions to be done'  
Sum of people + Simulator Job-aids(SA) + technology is equal



Low level of Simulator Based Job Aids



High level of Simulator Based Job Aids



# Reasons for CTA

- In order to understand how operators act upon the world around them, it is necessary to understand what goes on inside their heads
- Particularly when the tasks they are doing are complex
- It is not enough to simply observe their behaviors
- It is also important to find out how they think and what they know
- how they organize and structure information, and what they seek to understand better
- ***CTA typically consists of distinct phases of knowledge elicitation, analysis, and knowledge representation.***

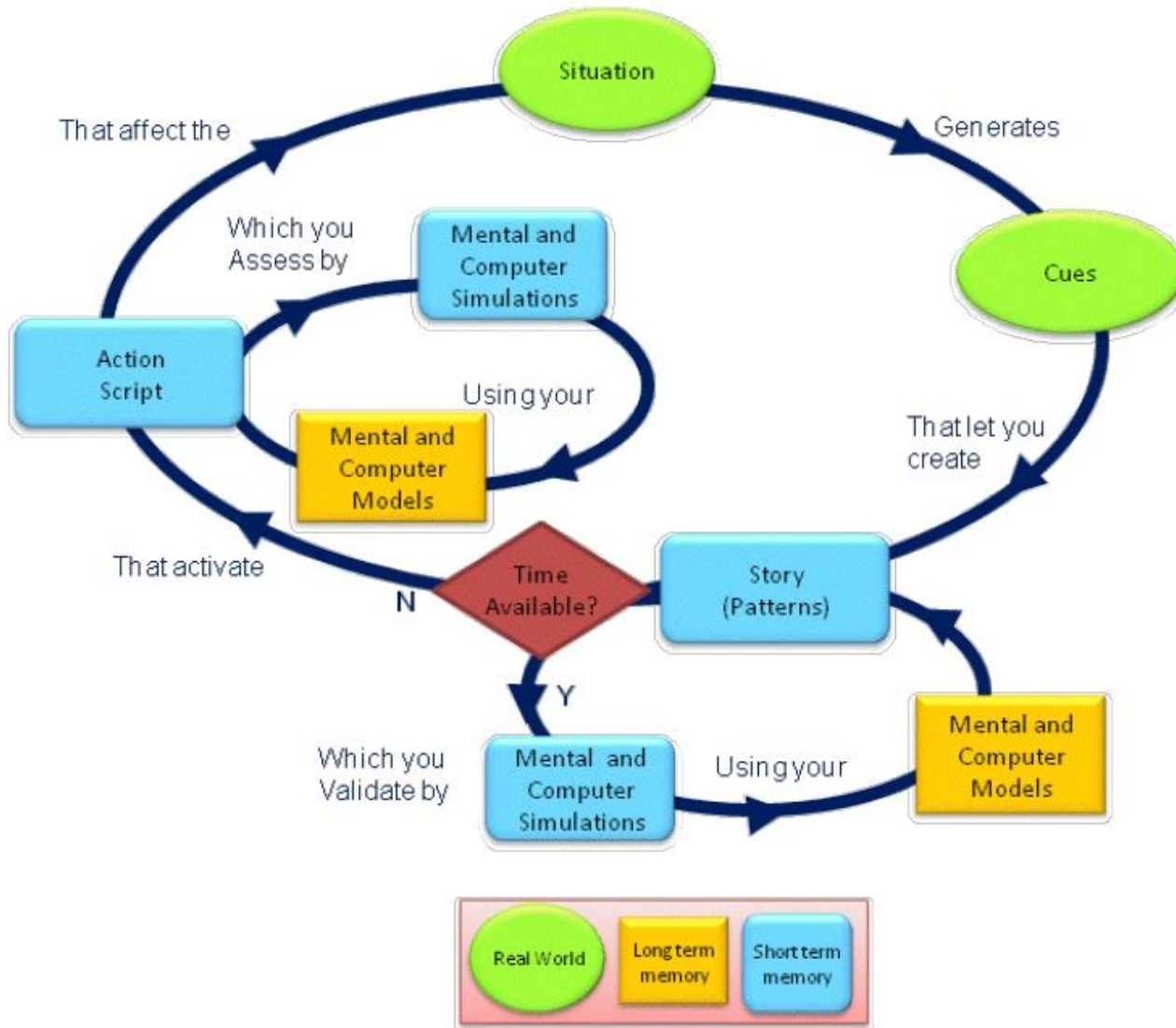
# Cognitive Task Analysis

- Methods and tools for mental processes behind observable behavior.
- CTA methods describe processes that underlie performance and the skills needed to respond to complex situations
- CTA boosts human performance in development of tools and training that support the cognitive processes required for a task.

# Knowledge Elicitation

- Extracting information, through interviews and observations, about cognitive events, structures, or models
- Information is provided by expert power system operators and engineers (SMEs)
- People with high levels of skill and knowledge in the domain of interest

# Operator Decision Model



# Operator Mental Models For Voltage Control

- Weak Bus / Strong Bus
- Open the Weak End First
- Pole and Beam Analogy for Voltage Collapse
- VARs don't travel far
- MVARs travel down hill on voltage
- Voltage see saw effect
- Run away transformer taps
- Get under the voltage
- Monitor MVAR reserves in local pockets
- Voltage collapse when 100 MW over 100 miles of 115 kV

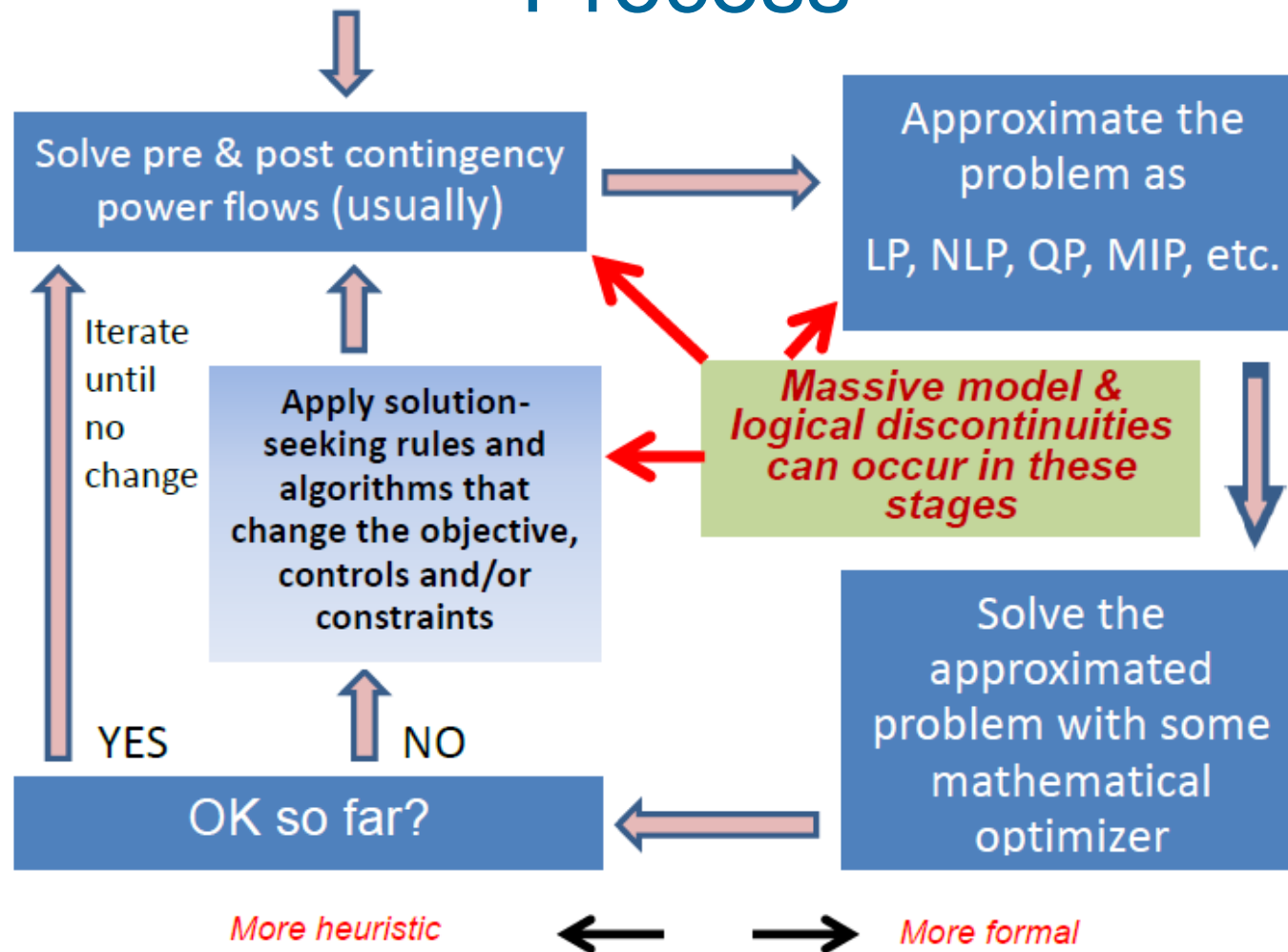
# Operator Mental Models For MW Control

- Make before Break
- MWs travel down hill on angle
- Reduce Generation at sending end of overloaded line
- Increase Generation at receiving end of overloaded line
- Channel the lines to serve specific loads
- Channel the generation into specific lines
- MWs will always find the load
- Load bottleneck – Generation bottleneck
- Wheel and Bungee Analogy for Angle Stability



# Applications of CTA for ACOPF

# Typical Iterative ACOPF Solution Process



# Decoupled ACOPF MW Angle Problem

- Adjust MW to limit MVARs flows in lines:
  - Generation re-dispatch
  - Interchange rescheduling
  - Line switching
  - Bus splitting
  - Phase shifter adjustment
  - Load shedding

# Decoupled ACOPF

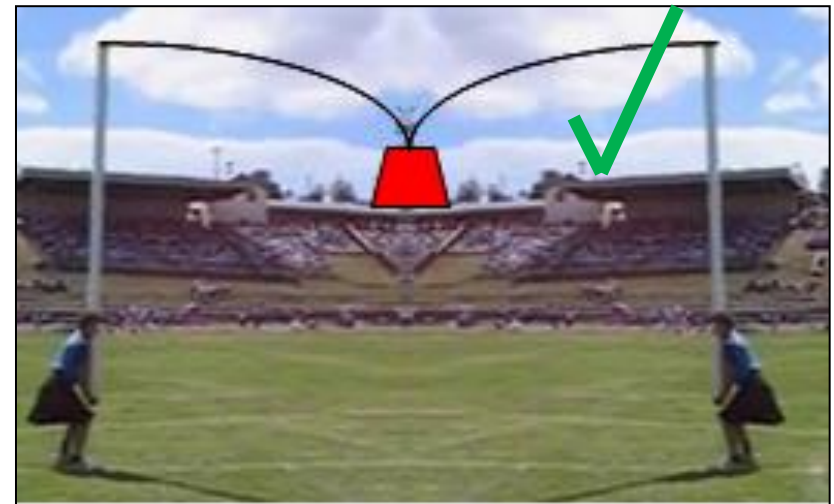
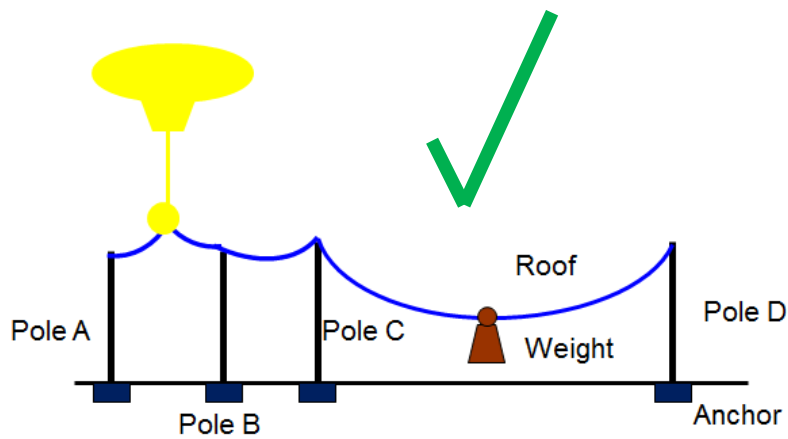
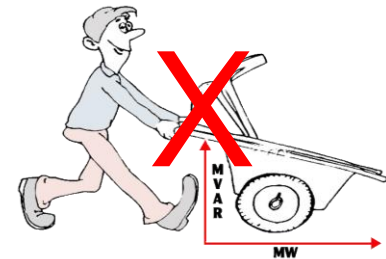
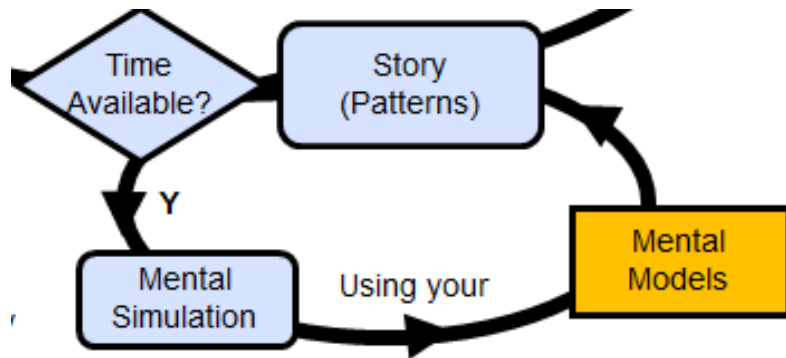
## MVAR - Voltage Problem

- Adjust MVARs to correct voltages
  - Add / remove capacitors
  - Add / remove reactors
  - Adjust generator kV set-points
  - Adjust transformer taps
  - Line switching (OOS for high voltage)
  - Load shedding

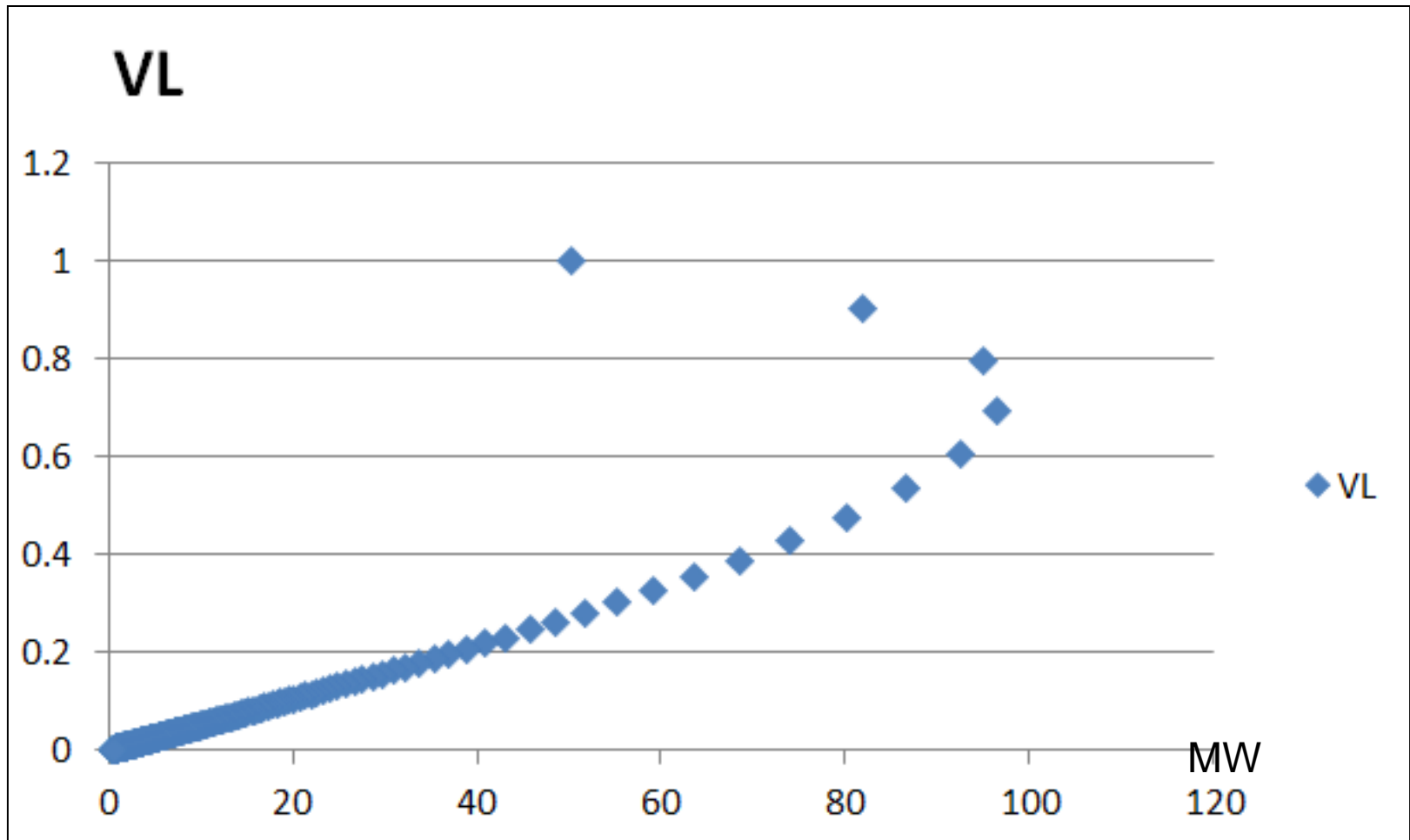
# Voltage Collapse

## Voltage and MW Coupling

# New Mental Models

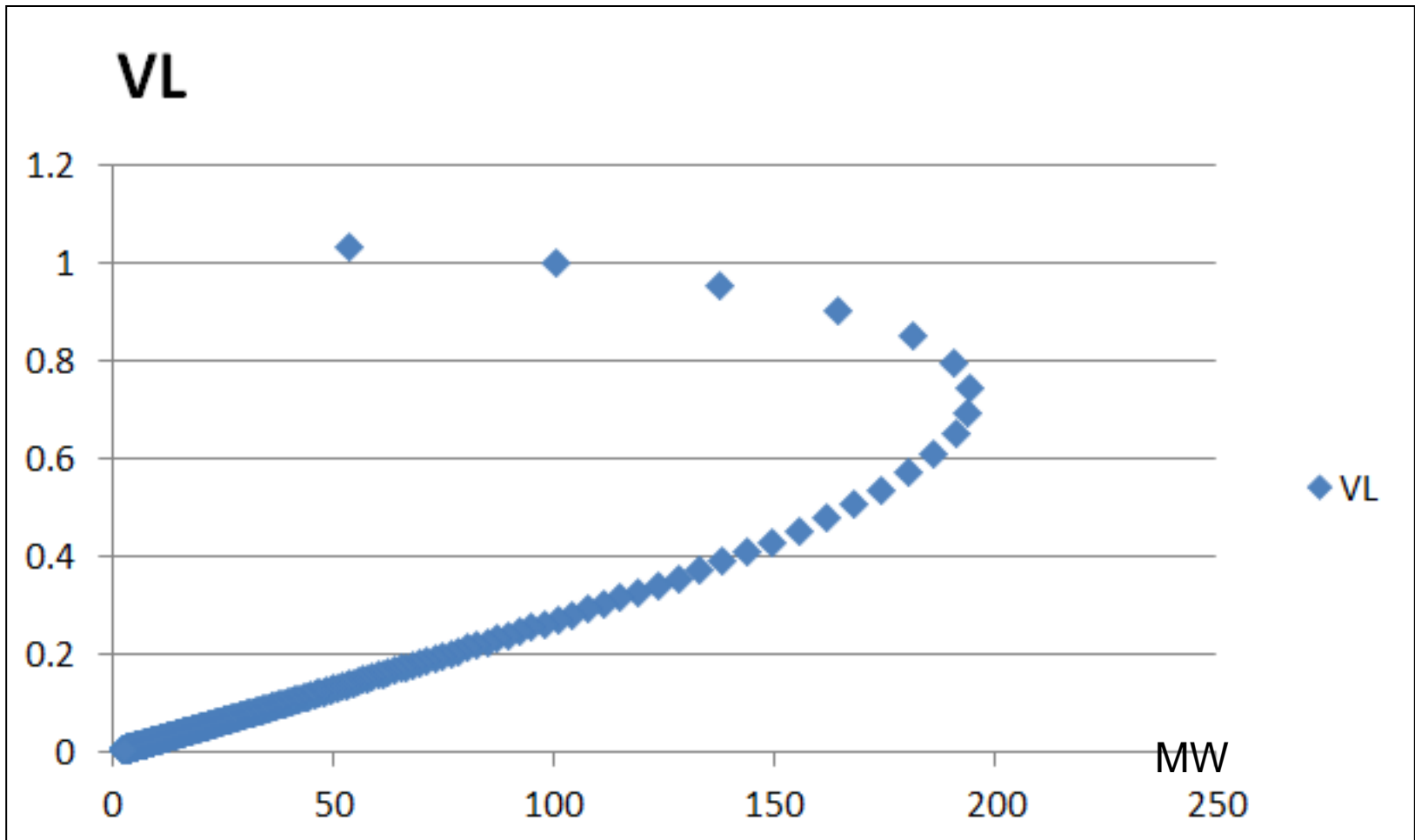


# P-V Curve for 100 mile 115 kV Line



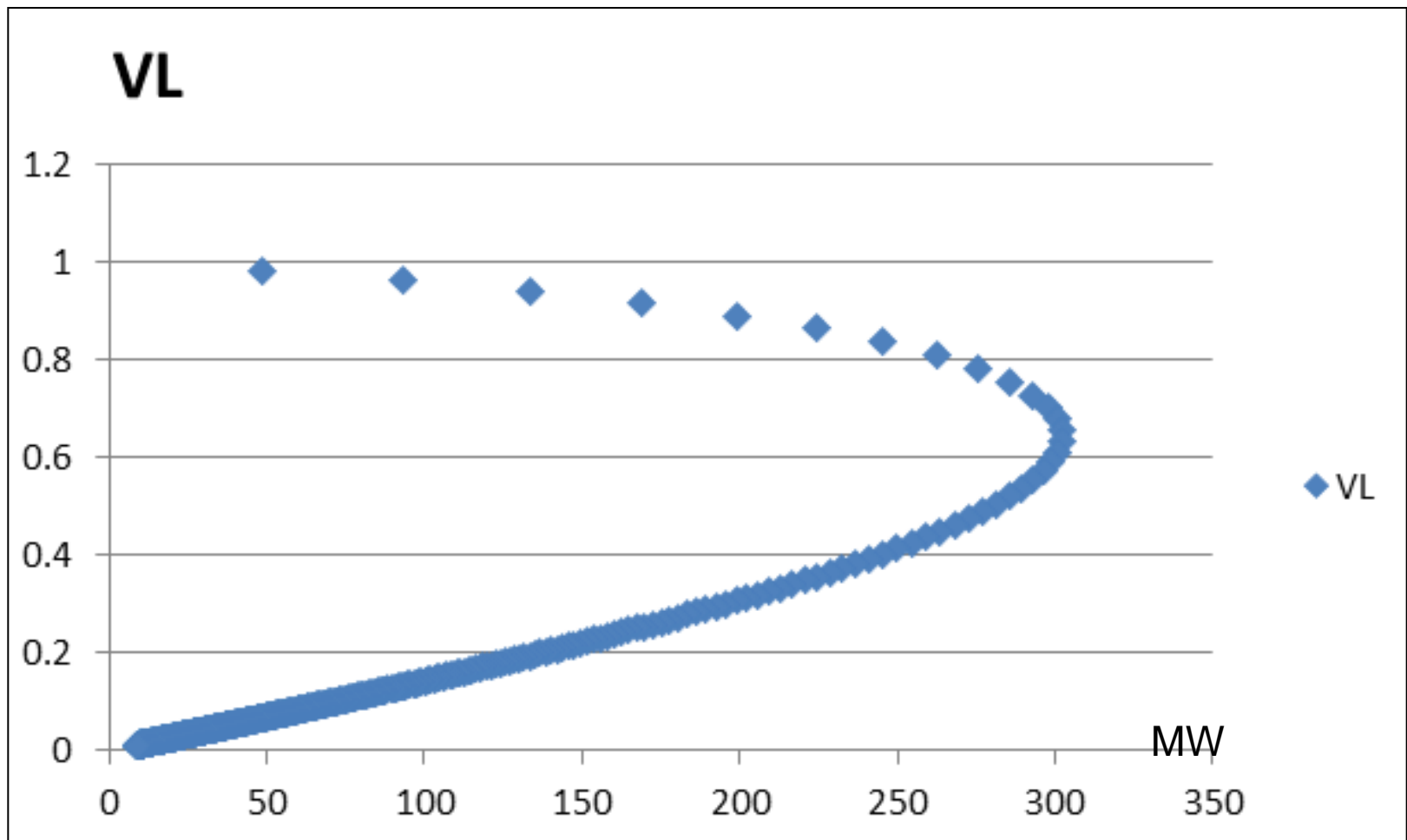
VSource = 1.05, PF =  
.999

# P-V Curve for 200 Mile 230 kV Line



VSource = 1.05, PF = .999

# P-V Curve for 300 Mile 345 kV Line



Vsource = 1.0, PF = .98

# Simulation Test Beds and Open Source Power Apps

# Need for Simulation Test Beds

IEEE 118 Bus (prototype)	Real World (market)
Bus Branch Models	Breaker Switch Models
Single User	Many Users
Study Application	Real-time Applications
User Driven	Event Drive
Input: User-defined Fields	Input: Real-time Measurement
118 Buses	50,000 Buses
Runs for Select Snapshots	Runs for Days
Not Mission Critical	Mission Critical
Not High Availability	High Availability
Runs Under Select Conditions	Runs Under All Conditions
Stand-alone Application	Part of a Complex System

# PG&E Restoration Training

- Regional drill by PG&E to train with neighbors
- All attendees work to restore PG&E Custom PowerSimulator model from irregular islands
- TOP/TOs, GOP/GOs present
- Takes place annually in Nov or Dec

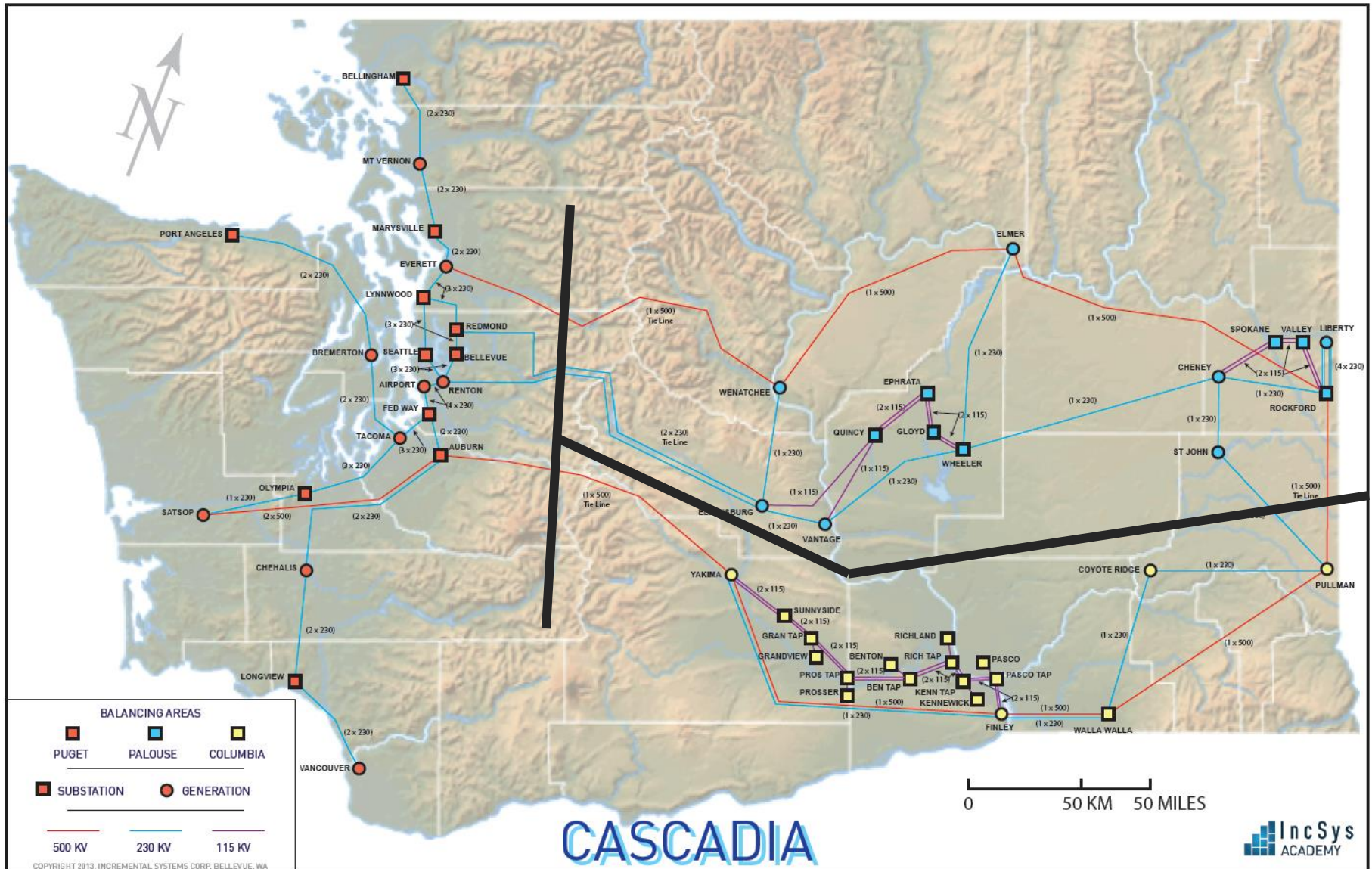


# Usability Tests at PNNL EIOC

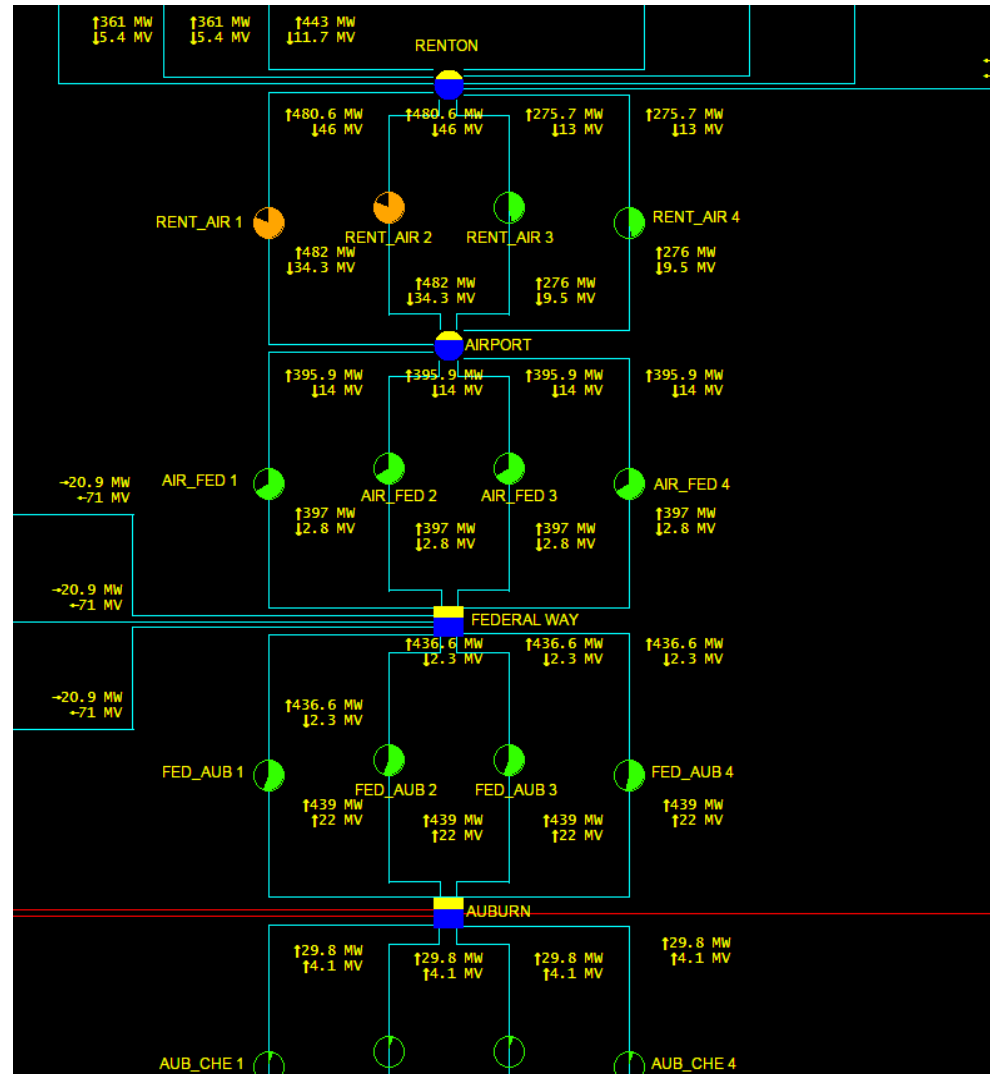
- Instructor lead NERC CEH Class of 16 Operators.
- Control and Experimental Groups



# Cascadia

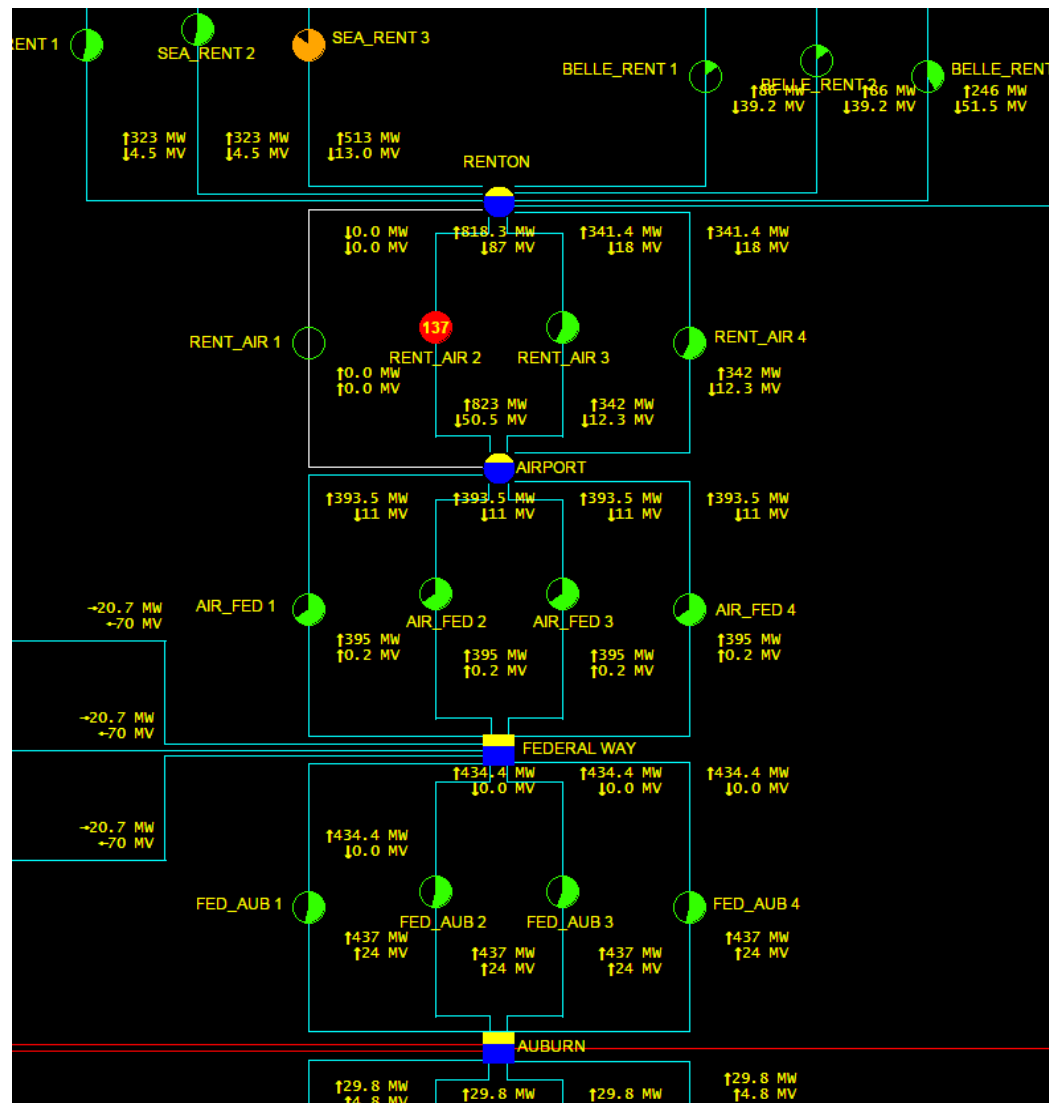


# Pre-Contingent Condition

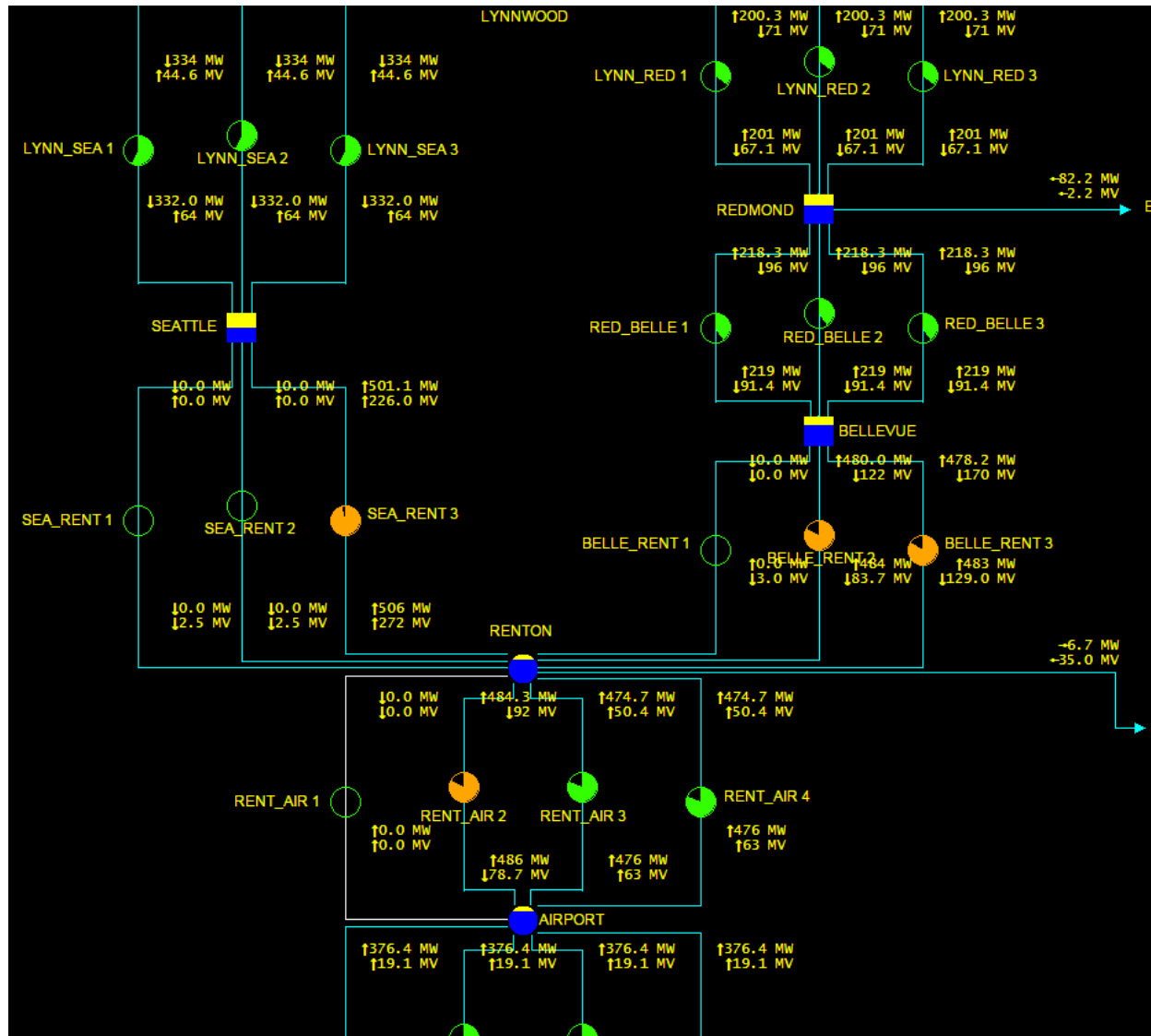




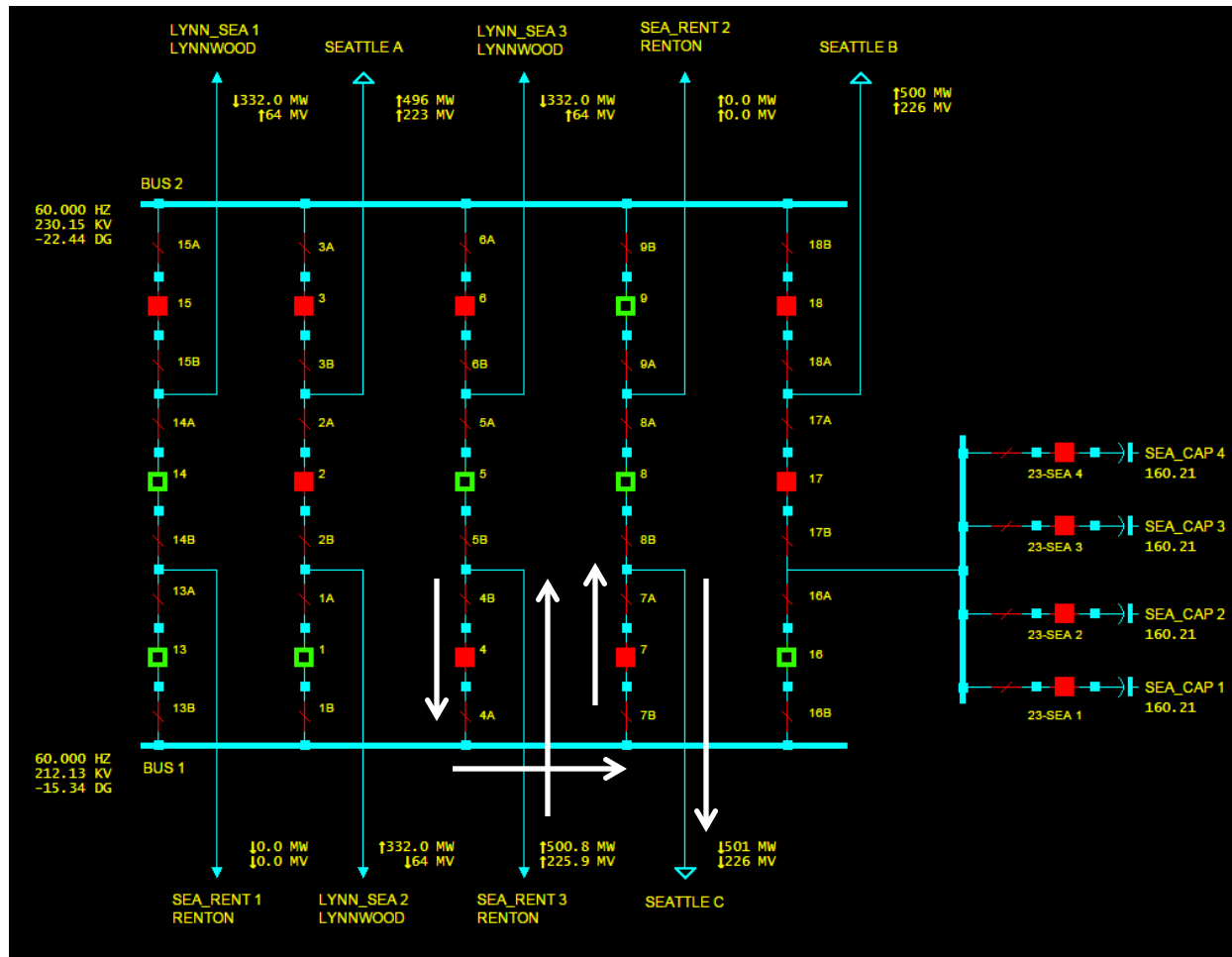
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# RATC Removes Overloads



# Load Channeling



# Benefits Simulation Test Beds

- Allow new control methods, analytical applications and visualization techniques to be thoroughly tested
- Feedback from system operators and trainers can guide the development
- Vital step to go from prototype to on-line deployment
- Time to go from Prototype to Production can be accelerated from years to months
- Java library of Open Source Power Applications is available at: <https://github.com/powerdata>

# Summary

- Get your NERC System Operator Certification
- Learn how expert system operators are solving the problem that you are researching today
- Use the latest in Simulation Test Beds
- Use realistic hypothetical system models
- Use high performance open source Power Apps
- Learn to program in Java